On SIM Dynamics and Control Modeling and Analysis

Bob Grogan

IMOS Workshop

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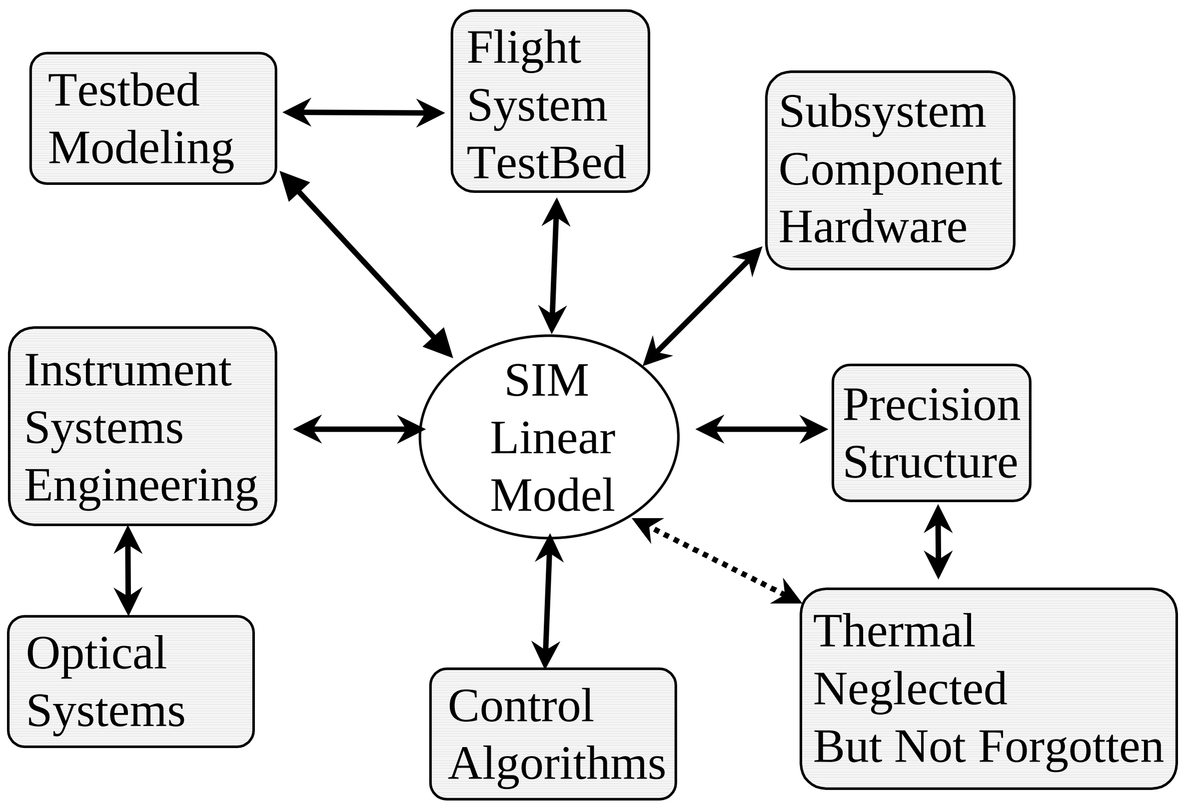
SIM

Technical Context Map



Philosophy of SIM Modeling

- Participate in Design by Defining Frequency Domain Spectrum Requirements
  - Model Built to Contain Physically Identifiable Parameters That May Be Traced To Requirements On Critical Features
  - Determine Dominant Modes/DOF and Fundamental Transmission Paths to Optical System
  - Perform Parametric Sensitivity Analysis on Dominate Modes
  - Define Requirements to Decouple Dynamics in Frequency Domain and Guarantee Performance
  - Levy Design Spectrum Requirements on Critical Points
    - Optics Mounts
    - Component Mounts
    - Gross Structure
    - Control Design
    - Disturbance Sources
  - Transition to Test Verified Component Models As Available
  - End Result Is Confidence In Design

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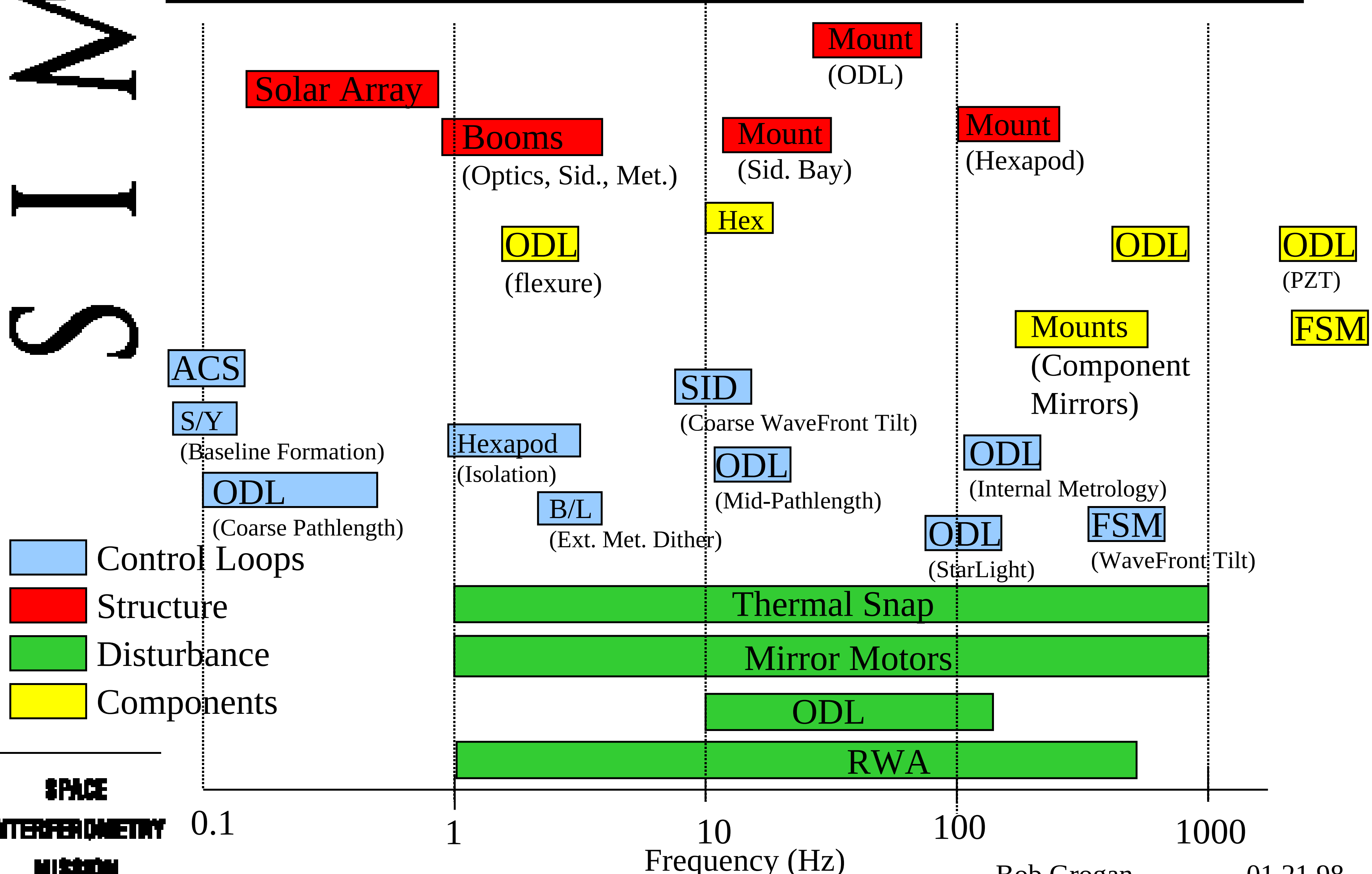
Preliminary Frequency Domain Mapping



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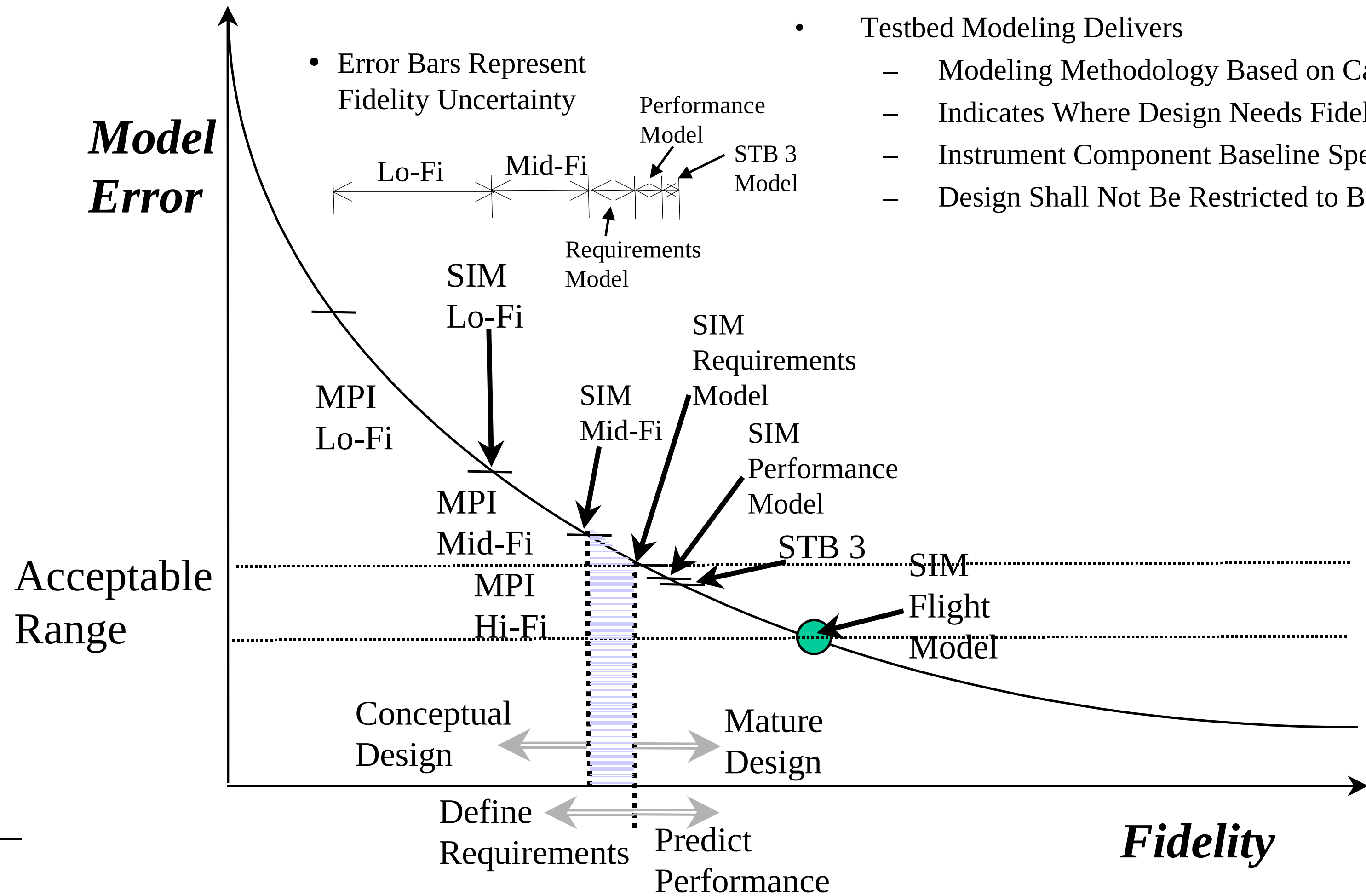
Evolution of Fidelity



- Testbed Modeling Delivers
  - Modeling Methodology Based on Case Study
  - Indicates Where Design Needs Fidelity
  - Instrument Component Baseline Specs
  - Design Shall Not Be Restricted to Be MPI-Like

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Role of Small Angle Performance Model

- Linear Performance Model
  - Assessment Of Control (Not Knowledge) Instrument Requirements and Performance Prediction For Observing Operating Mode (Assuming Star Is Acquired and Instrument Is Tracking)
    - End-to-End Optical Pathlength Performance Analysis From Disturbance to Fringe Visibility For Guide and Science Baselines
    - End-to-End Pointing Performance Analysis From Disturbance to Wavefront Tilt For Guide and Science Baselines
  - Assessment Of Sub-Component Requirements/Performance/Architecture
  - Control Algorithm Development Testbed (Spacecraft and Instrument)
  - Frequency & Time Domain Analysis
- Relationship With Non-linear SIM Simulator
  - Astrometric Performance Simulation
  - Linear Model Has Been Integrated With DARTS Flexible Multi-Body Software
  - Nonlinear Simulation Will Be Used To Evaluate The Design Requirements Built Into Linear Performance Model On Acquisition and Imaging Modes

State of the SIM Model

- FEM
  - Siderostat & Metrology Boom Modeled As Beams
  - Optics Boom Modeled As Rigid Body
  - Mass and Stiffness Added For All ODL's & FSM's
  - Mass and Stiffness Added For All Siderostat Bay Mounts
  - 8 Delay Lines - 4 Active, 4 Passive6 Axis Passive Isolation
  - 1200 DOF
  - 334 Modes
- Optics Model
  - 3 Baseline Linear Optical Model
    - Prescription Includes: 7 Siderostats, 7 Beam Compressors, 7 FSM, 4 Beam Combiners, 4 Active Delay Lines, 4 Passive Delay Lines
  - Siderostat Pair Forming Baseline Is Selectable
  - Ray Traces Calculated For All Baselines Simultaneously

State of the SIM Model

- Integrated Model
  - Linear FEM & Optics Model Integrated in State Space Form
  - Inputs
    - RWA Forces & Torques
    - Delay Lines - > VC & PZT For All Baselines
    - FSM X & Y Tilts In Actuator Coordinates For All Baselines
  - Outputs
    - OPD Starlight & Internal Metrology For All Baselines
    - Wavefront Tilt in X & Y Detector Coords For All Baselines
    - Attitude & Rate
- Control Model
  - Linear Compensators Designed By Shaping Loop Gain
  - Represented In State Space Form
  - Optics and ACS Loops Closed

SIM 3 BaseLine Integrated Model

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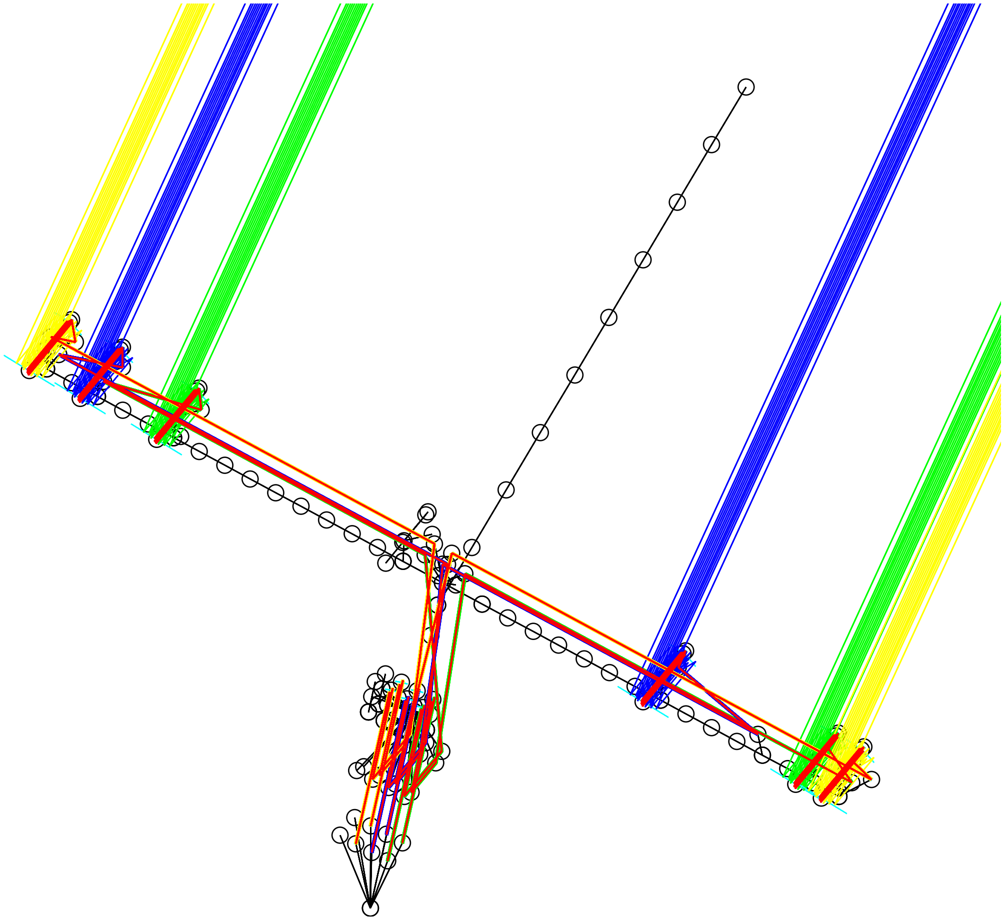

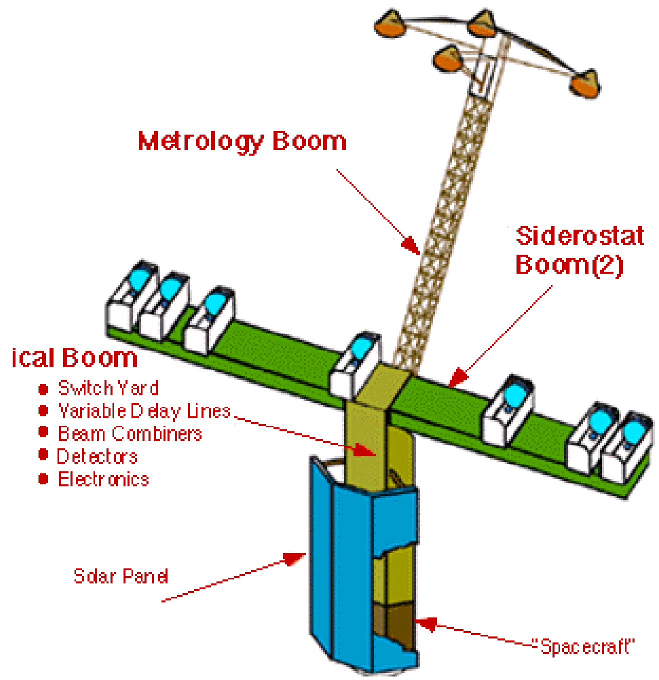

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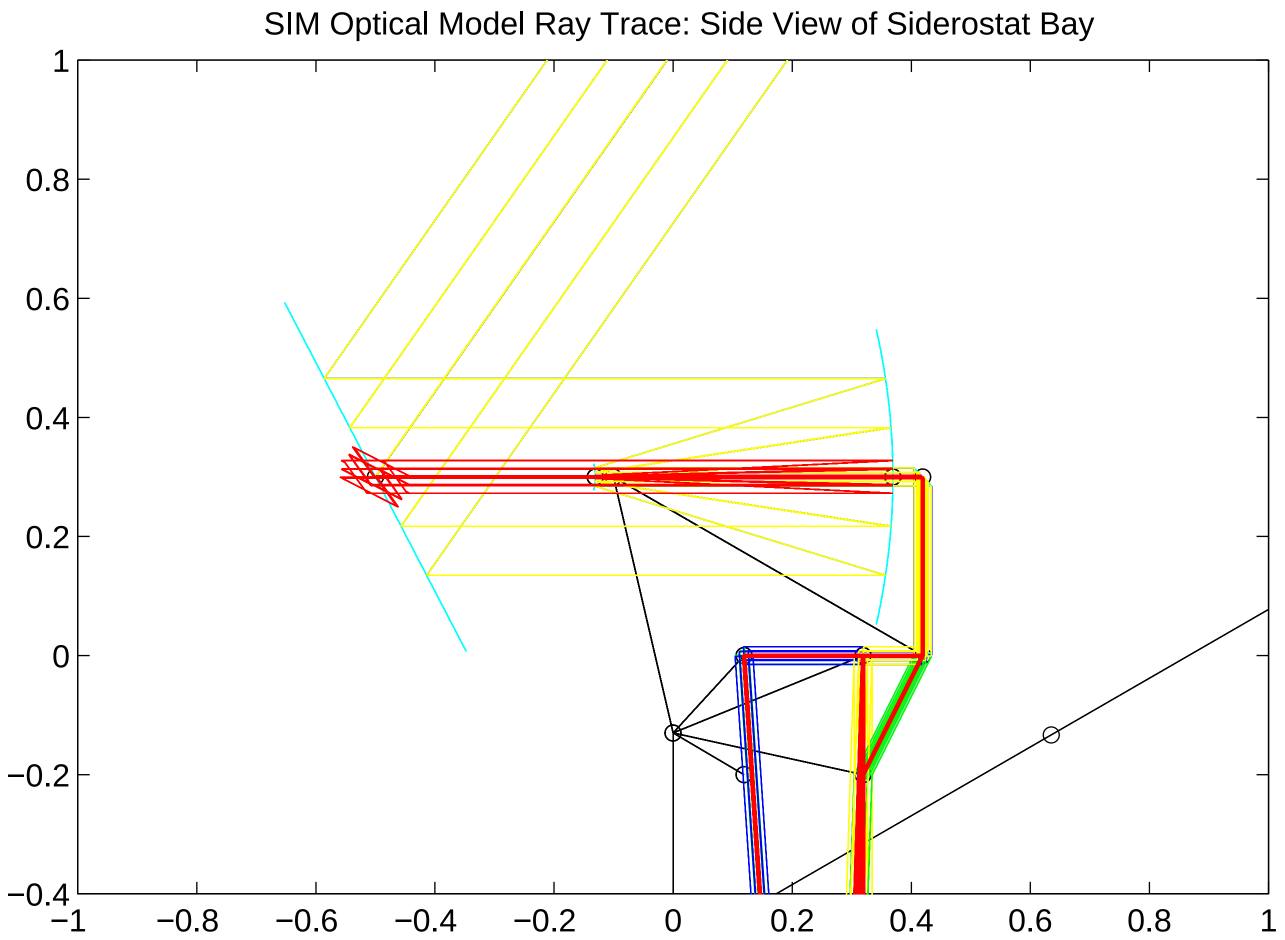
3 Baseline Integrated Model (Sid. Bay View)



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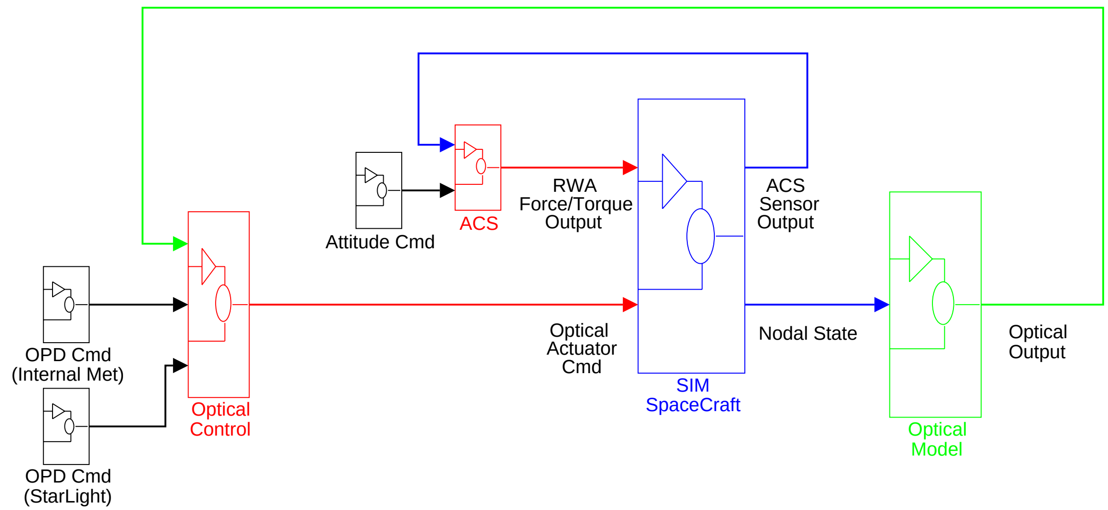
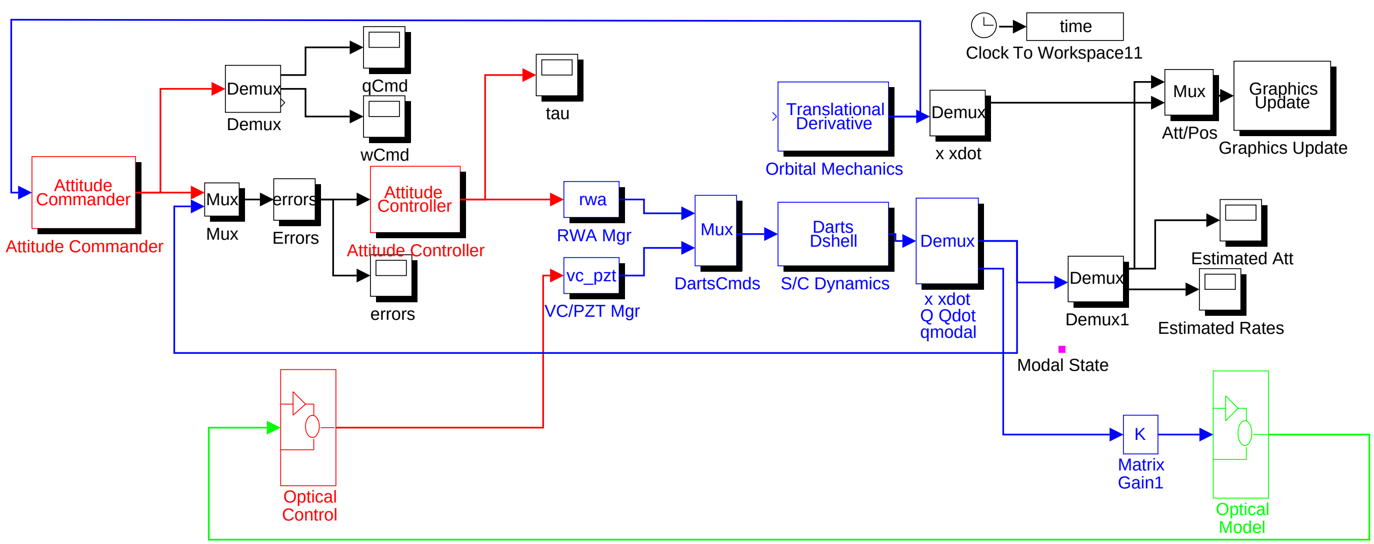
Simulink Block Diagram





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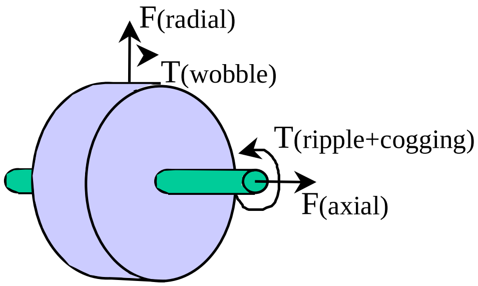
Disturbance Analysis

- Hubble Space Telescope Harmonic Disturbance RWA Model
  - Model Force/Torque Induced Vibration as Blocked Force
  - Assume Spin Motor Disturbance (Ripple and Cogging) Small
  - Stochastic Broadband Model
  - Discrete-Frequency RWA Model
    - Sweep over wheel speeds (0 to 3000 RPM)



- OPD vs. RPM
  - Each Point Represents Standard Deviation of the Discrete Frequency PSD of OPD Resulting From the Disturbance of a Single RWA at a Given Speed

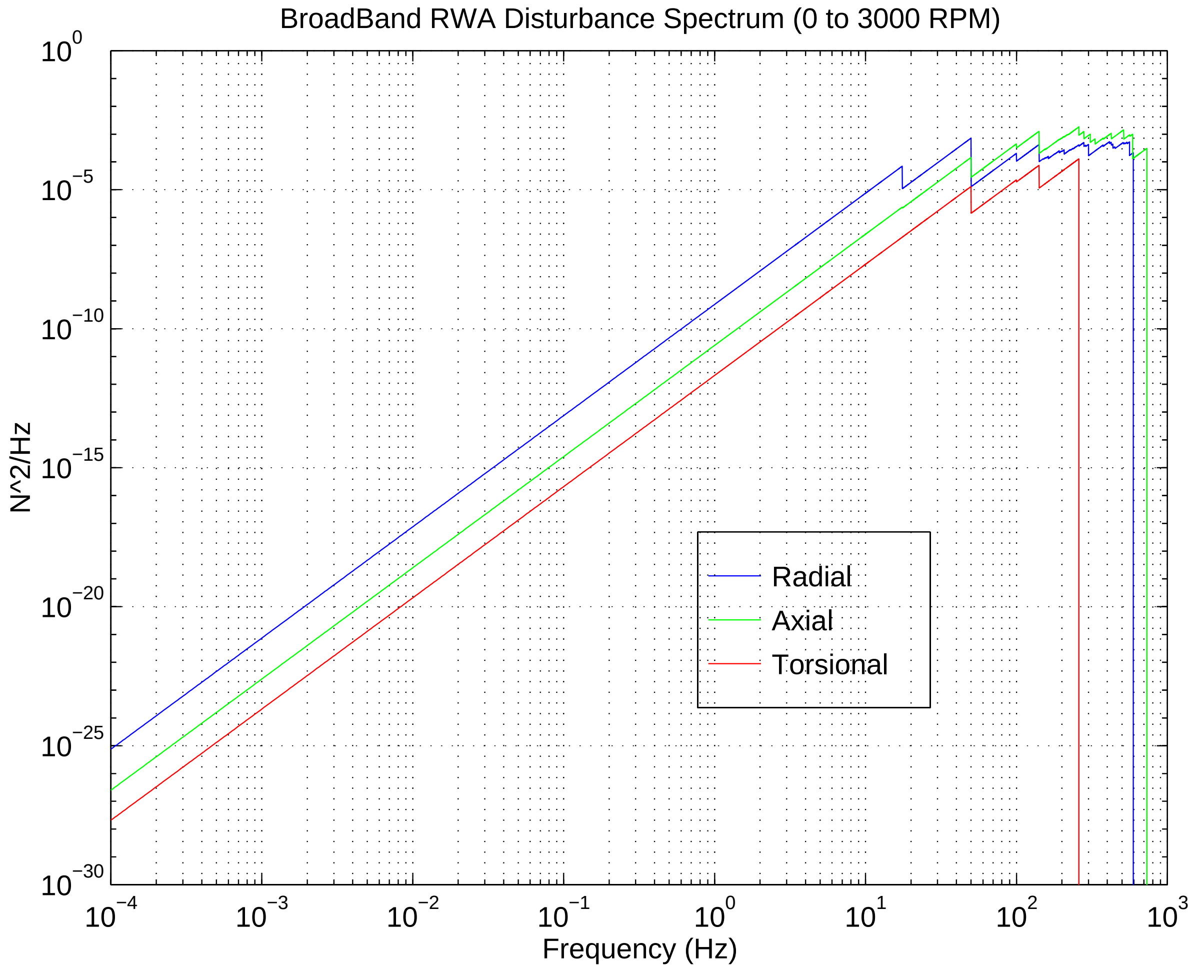
$$IV(t) = \sum_{i=1}^{n} C_i\, f_{RWA}^{2} \sin\left(2\pi h_i\, f_{RWA} t + \phi_i\right)$$

$$\sigma_{opd}^{2}(f_{RWA}) = \sum \int_{-\infty}^{\infty} \left| G(j\omega)_{\frac{OPD}{RWA}} \right|^{2} \Phi(\omega, f_{RWA})\, d\omega$$

- RWA High Frequency Signature Is Unique
  - Bearing Geometry, Bearing Race, Cage Speed, Operating Temp, Lubrication, Life
  - Model Flexibility Rolloffs With Parameterized Filters
  - Housing Flexibility, Bearing Impedance (100 Hz)
  - Statistically Bound Problem Using Many RWA Models

Stochastic Broadband HST RWA Model

- Radial Force Disturbance PSD Assuming Uniform Random Variable Wheel Speed Over [0,3000] RPM



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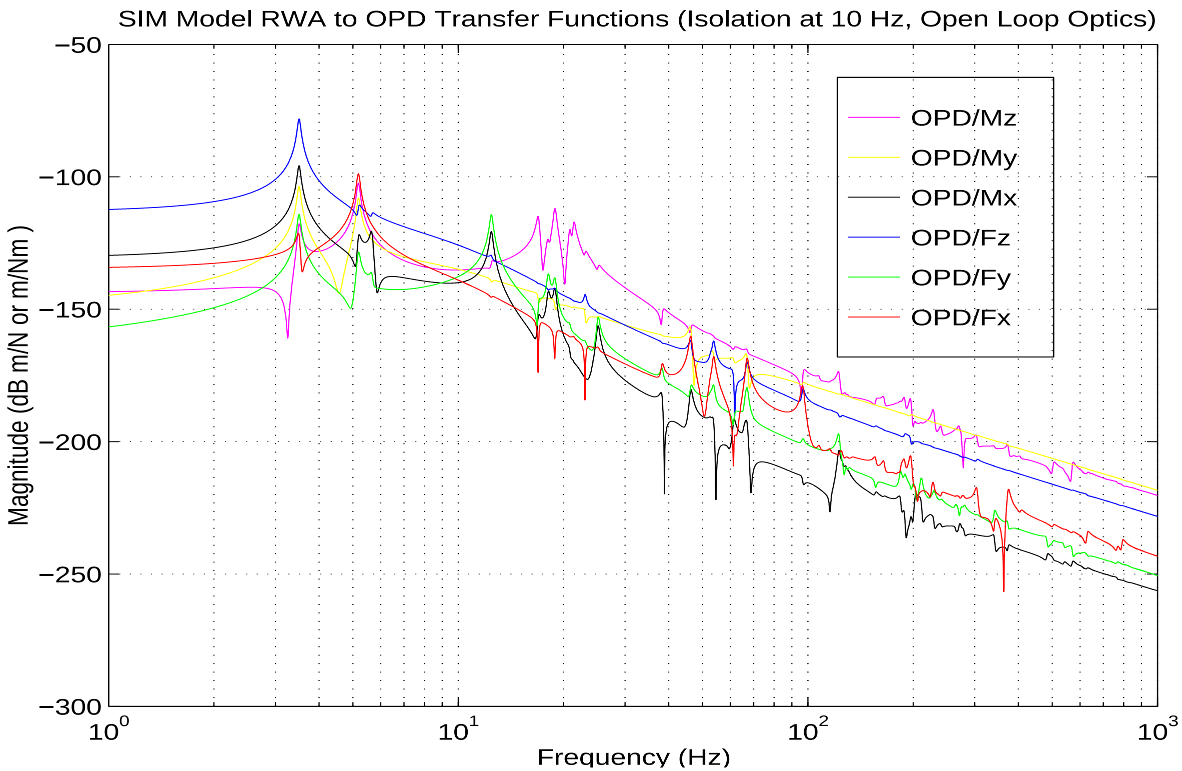
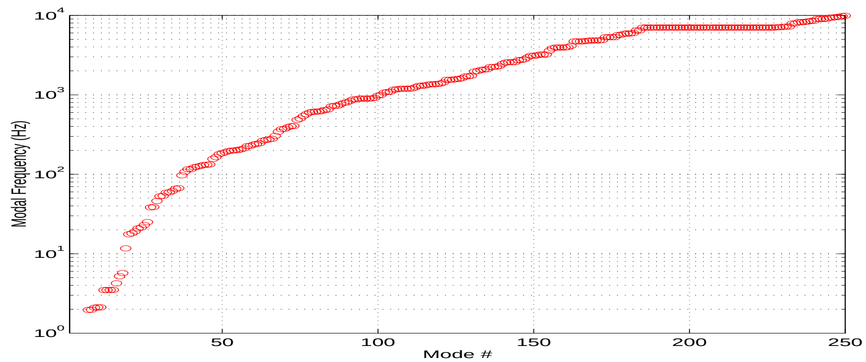
RWA Disturbance to OPD Transfer Function





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RWA Disturbance Induced OPD Variation

(Hardmounted RWA, Active Optics Loops Open)

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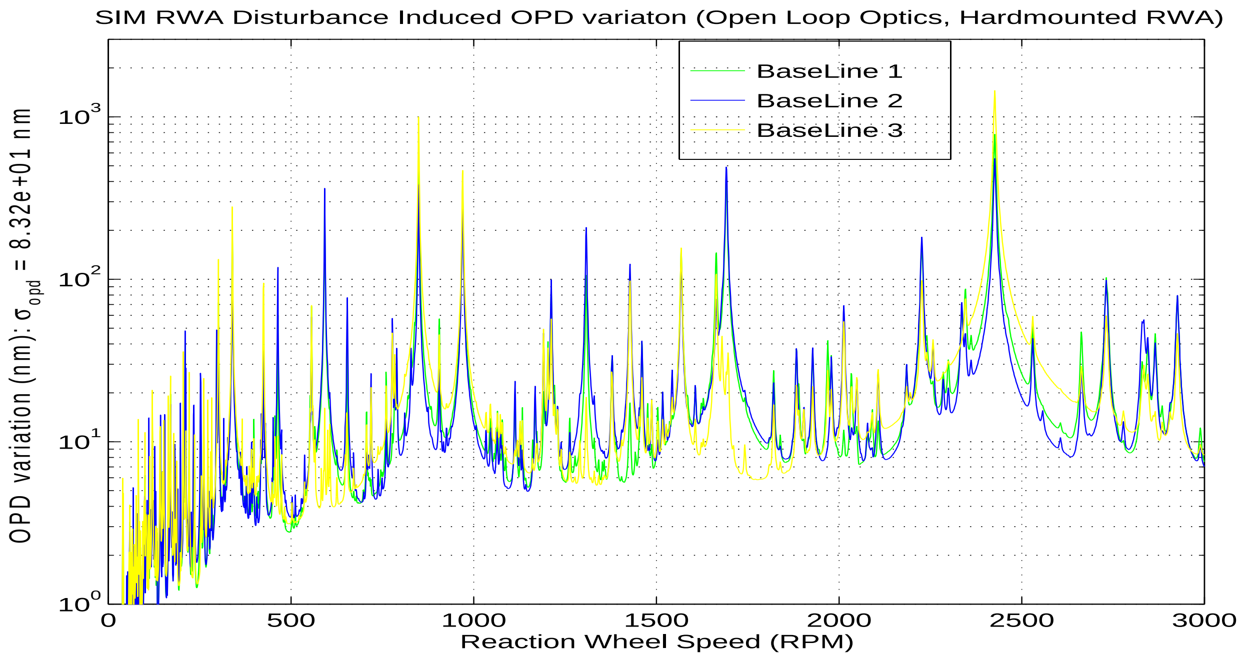
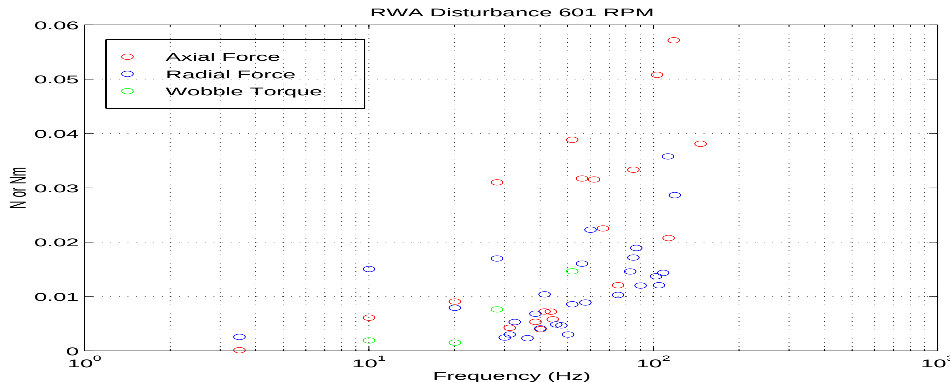
- Each Point Represents Standard Deviation of the Discrete Frequency PSD of OPD Resulting From the Disturbance of a Single RWA at a Given Speed





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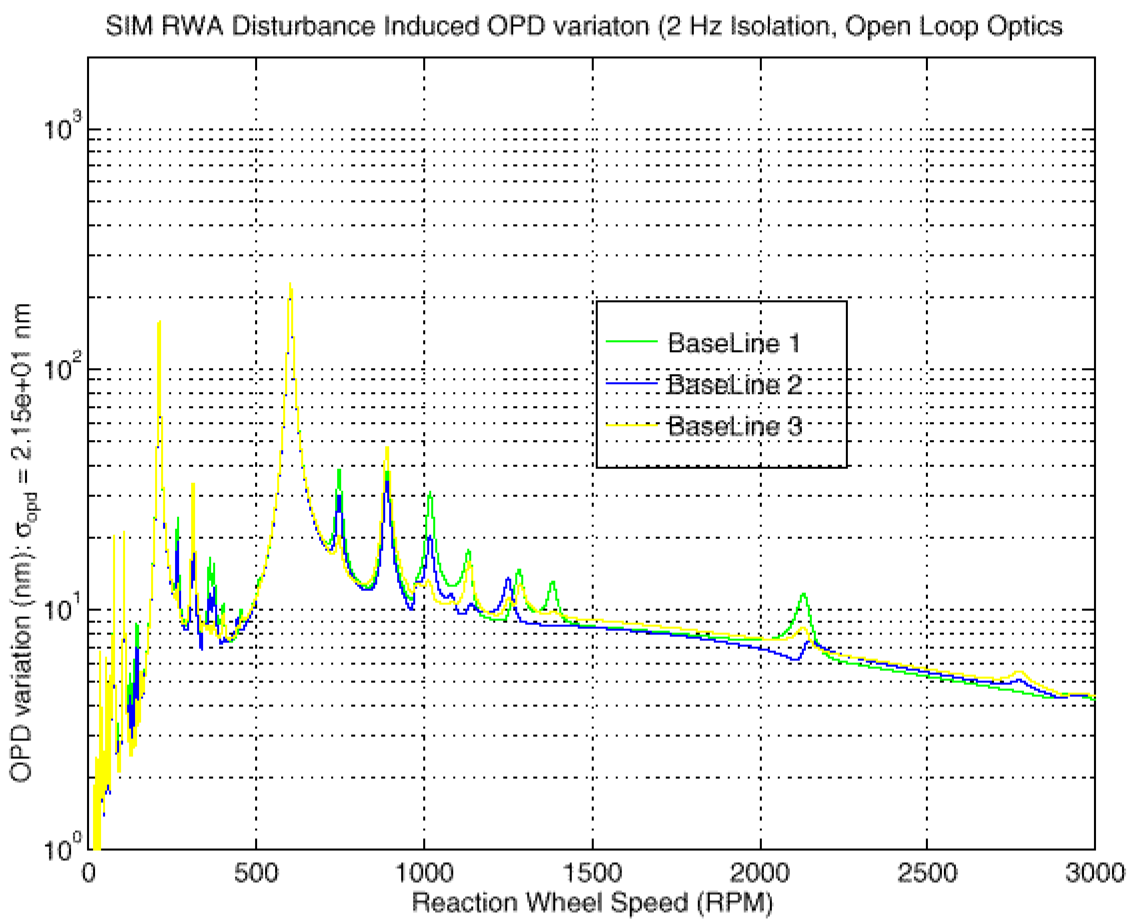
RWA Disturbance Induced OPD Variation

(2 Hz Isolation, Active Optics Loops Open)



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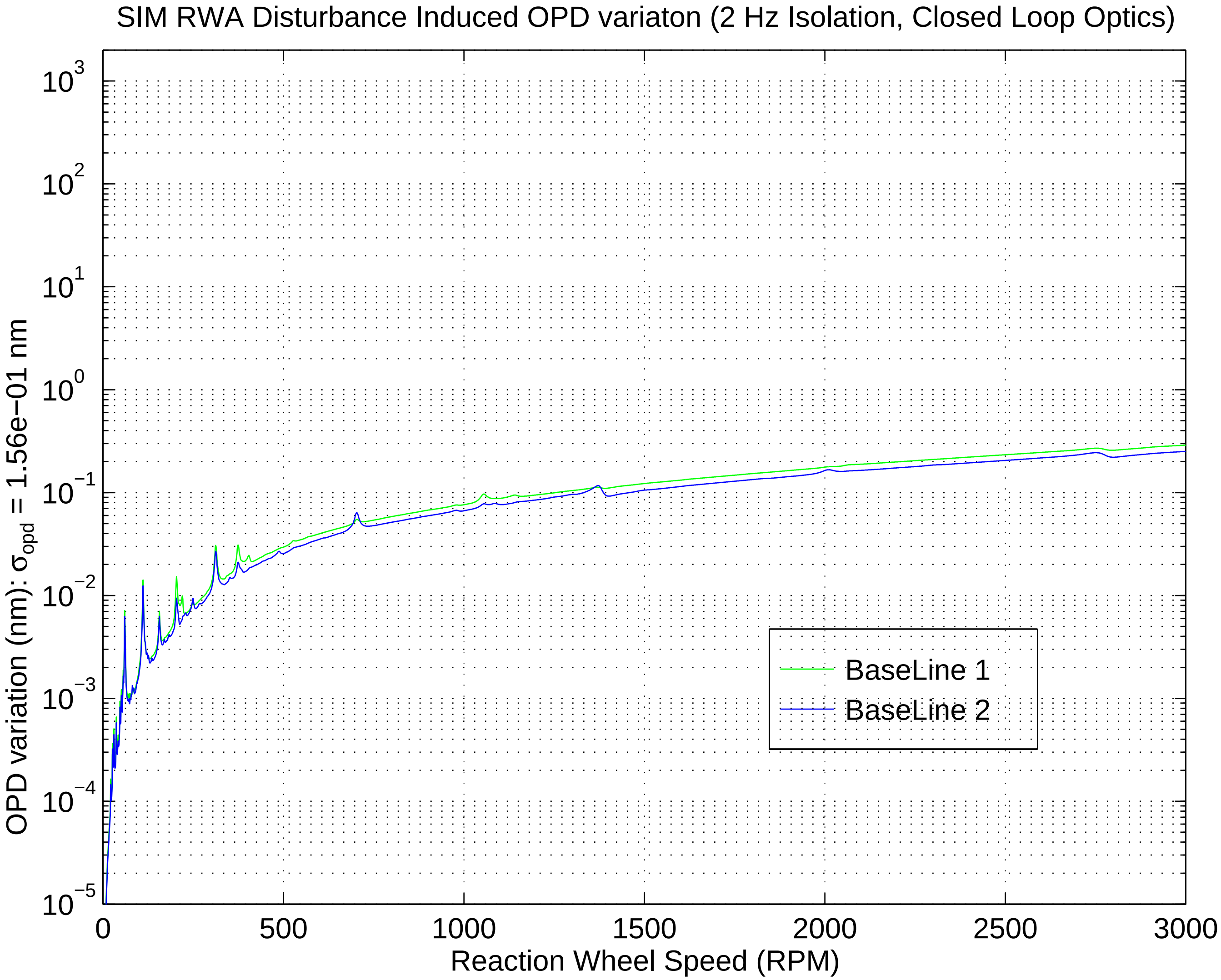
RWA Disturbance Induced OPD Variation

(2 Hz Isolation, Optics Loops Closed)



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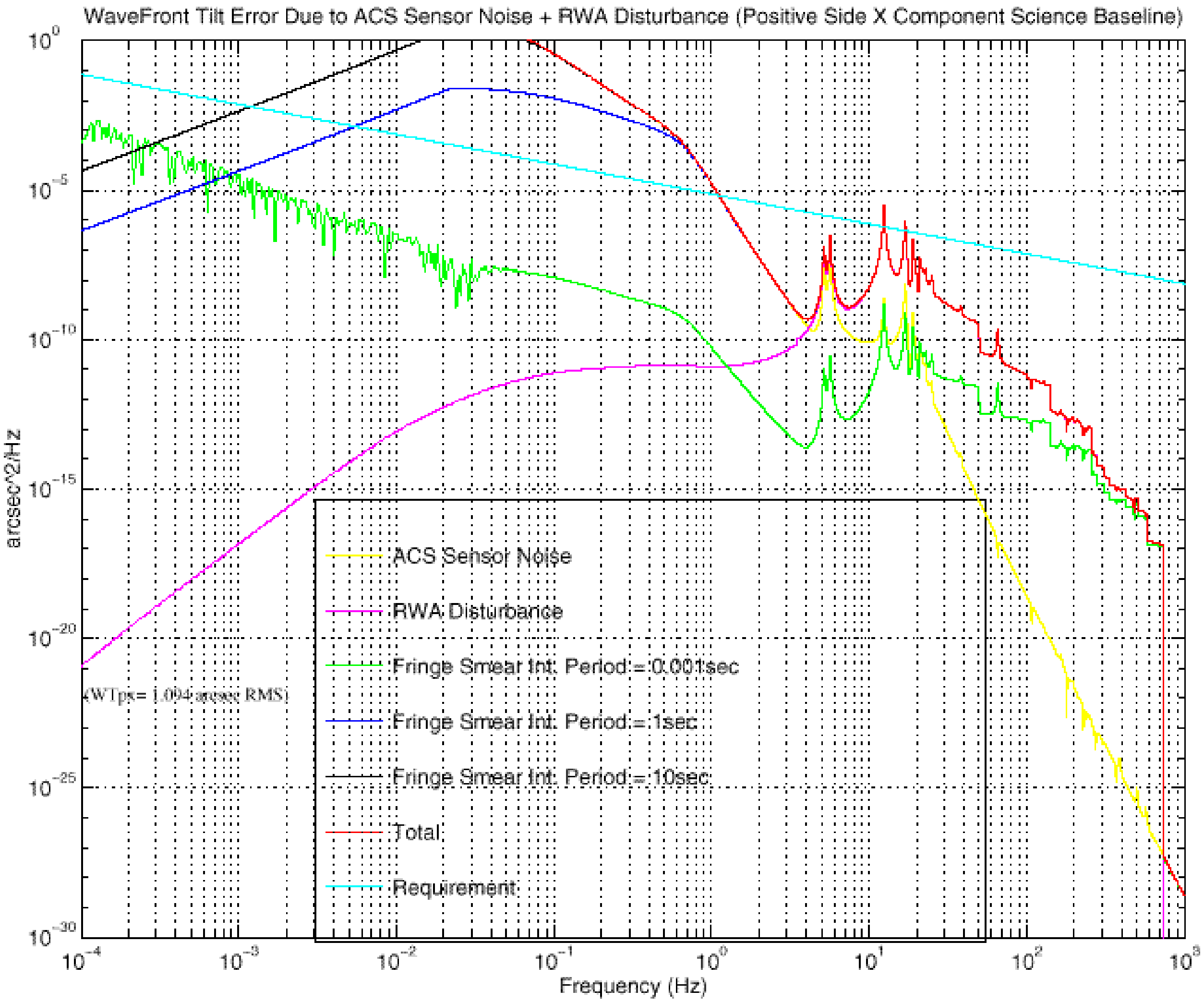
ACS Sensor Noise & RWA Disturbance Induced Wave Front Tilt



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